



FROM TECHNICAL TO ETHICAL
FROM CONCEPT GENERATION TO EXPERIMENTATION



NAVAL
POSTGRADUATE
SCHOOL

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MBARI's Autonomous Systems Program for Lagrangian Ocean Studies

by Kanna Rajan, Principal Researcher for Autonomy, MBARI

<http://www.mbari.org/staff/kanna/>

The Monterey Bay Aquarium Research Institute's (MBARI) Autonomous Systems group has been engaged in design, development, test and deployment of an intelligent adaptive controller for robotic systems. The Teleo-Reactive EXecutive (T-REX) has been deployed on a Dorado class AUV for coastal ocean studies ranging from plume detection, sampling Intermediate Nepheloid Layers (fluid sheets of nutrient rich suspended particulate matter that originate from the sea floor), ocean fronts and dynamic features such as advecting chlorophyll patches. T-REX uses Artificial Intelligence (AI) based automated Planning and Execution to close the sense-plan-act loop; sensors provide real-time estimates of critical science parameters such as chlorophyl fluorescence, Nitrate and backscatter to guide the vehicles navigation and control as well as ten onboard water samplers. Machine Learning is used offline to build a stochastic Hidden Markov Model (HMM) of a feature of interest which is embedded along with the T-REX controller; in appropriate circumstance the HMM informs the controller which in-turn replans on the fly to trigger water-sample acquisition. T-REX has a rich legacy with its embedded planner having flown on two NASA missions, one onboard the Deep Space 1 mission in 1999 and the other for ground-based mixed-initiative control of the two Mars Exploration Rovers which continues to operate from JPL. Fig.1 shows a high-level architectural view of the controller.

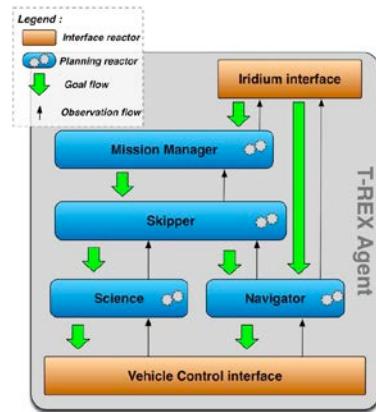


Fig.1 The embedded T-REX agent which uses a *divide-and-conquer* strategy for solving automated inference on an Autonomous Underwater Vehicle.

T-REX is a general-purpose controller and scales well to complex control problems where adaptation and re-planning are integral. In doing so, it has opened a new class of problems that require a balanced consideration of mission objectives, environmental conditions and available resources. One recent set of field experiments for instance have focused on Lagrangian studies of coherent patches of advecting water with resident communities of micro-organisms.

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CRUSER News Contributions

Short articles of about 200-300 words are needed for future CRUSER News'.

Please contact Lisa Trawick at cruser@nps.edu for additional information.

| Report Documentation Page | | | <i>Form Approved OMB No. 0704-0188</i> | |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|-----------------------------------------------------|-----------------------------------------------------------|---------------------------------|
| <p>Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.</p> | | | | |
| 1. REPORT DATE MAY 2011 | 2. REPORT TYPE | 3. DATES COVERED 00-00-2011 to 00-00-2011 | | |
| 4. TITLE AND SUBTITLE Cruser News. Issue 3, May 2011. | | 5a. CONTRACT NUMBER | | |
| | | 5b. GRANT NUMBER | | |
| | | 5c. PROGRAM ELEMENT NUMBER | | |
| 6. AUTHOR(S) | | 5d. PROJECT NUMBER | | |
| | | 5e. TASK NUMBER | | |
| | | 5f. WORK UNIT NUMBER | | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School, Consortium for Robotics and Unmanned Systems Education and Research (CRUSER), Monterey, CA, 93943 | | 8. PERFORMING ORGANIZATION REPORT NUMBER | | |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | | 10. SPONSOR/MONITOR'S ACRONYM(S) | | |
| | | 11. SPONSOR/MONITOR'S REPORT NUMBER(S) | | |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited | | | | |
| 13. SUPPLEMENTARY NOTES | | | | |
| 14. ABSTRACT | | | | |
| 15. SUBJECT TERMS | | | | |
| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT Same as Report (SAR) | 18. NUMBER OF PAGES 4 |
| a. REPORT unclassified | b. ABSTRACT unclassified | c. THIS PAGE unclassified | | |

DIRECTOR'S CORNER

INNOVATIVE AND REVOLUTIONARY CONCEPT GENERATION IS KEY TO ENSURING OUR RAPIDLY EVOLVING UNMANNED SYSTEMS BECOME FUTURE FORCE MULTIPLIERS. CRUSER WILL PROVIDE A VENUE TO COORDINATE CONCEPT GENERATION OPPORTUNITIES SUCH AS WARFARE INNOVATION WORKSHOPS, WARGAMES AND RESEARCH. IT WILL ALSO PROVIDE A VEHICLE TO SHARE RESULTS ACROSS THE COMMUNITY OF INTEREST.

CAPT (RET) CAROL O'NEAL, USN
CRUSER DIRECTOR INNOVATION & CONCEPT GENERATION



The Robot with the Machine Gun was Particularly Popular.....

by Prof John Jackson, Naval War College, Newport, RI

The list of “guest speakers” is pretty impressive: SCAN EAGLE, RAVEN, WASP, SWITCHBLADE, SUGV, PACBOT, DRAGON-RUNNER, TALON, BLUEFIN UUV.... and other platforms including the Mobile Autonomous Armed Robot System (MAARS).... The weapons-carrying robot mentioned above! These systems have given students a hands-on experience during their senior service-college experience.

Since the fall of 2009, the Naval War College has been offering an elective course entitled “Unmanned Systems and

Conflict in the 21st Century.” The course is taught in the spring and fall trimesters each year to students from all military services, government civilian employees, and international officers.

A key lecturer is Dr. P.W. Singer, author of “Wired for War” the New York Times bestseller, who has helped create and teach the course. His book is one of the primary texts used, along with the DoD Unmanned Systems Roadmap and other government documents. (The entire course syllabus is available at <https://wiki.nps.edu/display/CRUSER/Navy+Education>).

According to the course developer and moderator, Professor John Jackson: “This course provides mid-grade and senior military officers with hands-on exposure to many of the systems now in use, and the opportunity to consider many of the issues that arise as the military services increasingly turn to robotic systems in all warfare domains.”

The 10-week course focuses on the capabilities and limitations of unmanned systems, and also reflects on the legal and ethical issues of their employment. Support from senior Navy leaders, experienced operators, and systems designers and developers insure that the coverage is more than just “PowerPoint” deep. The class has traveled to the Massachusetts Institute of Technology (MIT) and to the Navy Undersea Warfare Center (NUWC) to observe their

research; and a Dartmouth University professor recently came to Newport to speak about Artificial Intelligence (AI) which included a discussion of “Watson,” the Jeopardy-playing robot.

In March 2010, Prof Jackson was called before the House Subcommittee on National Security to testify about his course and how the students were reacting to this new technology. “The House Subcommittee was investigating how robotic systems are being procured and employed, and they wanted to insure that the potential benefits of these systems were being effectively realized” said Prof Jackson. “I was able to speak about the positive attitude toward this evolving technology that I detected in the military students enrolled in these classes, and their interest in the legal and ethical ramifications of their use.”

The Naval War College is working closely with the Army War College, the Industrial College of the Armed Forces, the Naval Academy, and the Naval Postgraduate School to share information and instructional materials. “I was pleased to recently join the CRUSER Community of Interest, and salute this new organization for playing a leading role in coordinating research and education in this evolving field,” Jackson said.

Anyone with questions about the Naval War College course should contact Prof Jackson at jacksonj@usnwc.edu.

CRUSER Community of Interest

The CRUSER Community of Interest Sign-up form wasn't operating properly from 19-26 April. If you signed up during this week, please complete the form again on our [website](#) or contact Lisa Trawick at cruser@nps.edu to verify your information was received.

The Legality & Ethics of Armed Autonomous Robots

by John S. Canning, Naval Surface Warfare Center, Dahlgren Division

We at NSWC Dahlgren began to seriously look at the weaponization of unmanned systems in late 2002. This was following the public announcements of the tactical use of HELLCLOUD missiles from Predator UAS. Like the Predator, virtually all of the existing armed unmanned systems (UxS) programs that we found then were based on “man-in-the-loop” control. The problem we had with this was that this meant that we were inserting a very expensive machine between the human and his weapon. For small numbers of machines this would likely not be a big issue, but for large numbers of machines this meant that the cost for conducting war was being driven up considerably.

While we understood that we were talking about the development of new systems, we also understood that, historically, the largest Total Ownership Cost item over the life of a system is the cost of personnel. Today we see a “one machine – many people” paradigm. We set about to find ways to get the human out of the weapons control loop in order to attempt lowering the Total Ownership Cost for our armed UxS. We needed to achieve a “One person – many machines” paradigm. We needed these machines to be able to decide for themselves when to pull the trigger.

We quickly came to the conclusion that the bigger hurdles in our quest to get the human operator “out-of-the-loop” would not be technical, but would be legal. For this reason, we scheduled a meeting on 23 September 2003, here at NSWC Dahlgren, with personnel from both the OSD Office of General Counsel, and the Navy’s Office of the Judge Advocate General (OJAG), International Law Division (Code 10). It was an historic meeting between lawyers and engineers.

We began the meeting by sticking our foot in our mouth when this author told the lawyers, “We understand you have problems with these machines deciding for themselves when to pull the trigger. What are your concerns?” A Marine Corps major with combat experience, also a lawyer from the Navy’s OJAG, immediately replied, “They could kill people!” In a split second of this reply two thoughts ran quickly through our head: (1) War is hell. (2) Men die. We immediately replied, “No, seriously, what are your concerns?” He replied, “That’s it - they could kill people!” He was deadly serious. During the remainder of the meeting, the lawyers proceeded to explain their stance to us, and more importantly, why they held it. It was an eye-opening event.

Law of Armed Conflict

This is what the lawyers told us: The history of warfare is as old as the history of mankind itself. From the earliest time, man has targeted man with the weapons of the day, be they rocks and stone clubs or Tomahawk cruise missiles. As the destructive capability of weapons has increased, so has the potential for incidental injury to civilians and collateral damage to civilian property. Additionally, military operations have moved to the urban population centers amplifying this risk. The Napoleonic era brought the advent of the theory of “total war,” where no parts of the enemy populations or infrastructure were exempt from targeting. At the turn of the last century, technology had outpaced

tactics, and World War I brought the carnage of modern weaponry used in trench warfare. Following WW I, purportedly “the war to end all wars,” was massive destruction wrought by WW II, and the use of the atomic bomb.

Full article available at <https://wiki.nps.edu/display/CRUSER/CRUSER+News+Articles>

MBARI (cont)

To track such a patch field experiments conducted in June, September and October 2010 and more recently in March 2011 used drifters some with attached sensors. T-REX on the Dorado was sent drifter GPS updates via Iridium, which were crosschecked for safety considerations on shore prior to re-transmission. A Lagrangian frame of reference required that the vehicle tracks be deform to preserve the 1 Km X 1 Km box around the moving drifter. In this way, scientists can take the accumulated sensor data and post-process to determine the environmental composition of the water mass as the drifter is moving thru the water-column. In this process, T-REX synthesized all the associated waypoints onboard on receipt of the GPS location of the drifter and a heading computed on shore. Fig. 2 shows a Lagrangian box around an advecting drifter; Fig 3. shows the two vessel cruise 100 Nm off the Central California coast. The R/V Wester Flyer is shown in the figure while the R/V Zephyr AUV support vessel is not.

T-REX is being deployed routinely on MBARI’s Dorado platform as part of the inter-disciplinary CANON (Controlled Agile and Novel Observation Network) program. Onboard autonomy will be coupled with on-shore autonomy using an Oceanographic Decision Support System to synthesize inputs from multiple data streams including remote-sensing, AUVs, moorings and aircraft and provide a single portal for situational awareness and to visualize and plan deployments. Further research in goal-oriented multi-vehicle coordination by the Autonomous Systems group is also being targeted to use this hybrid approach with human-in-the-loop control. T-REX components on shore and onboard will then loosely coordinate where, how and when vehicles will observe and sample in the coastal ocean.

T-REX has also been deployed on terrestrial robots for coordinating different planners for a personal robot and is also being used for a European Space Agency project to demonstrate fully autonomous operations on a planetary rover testbed demonstrating opportunistic science.

Additional details and publications are available at <http://www.mbari.org/autonomy/>.

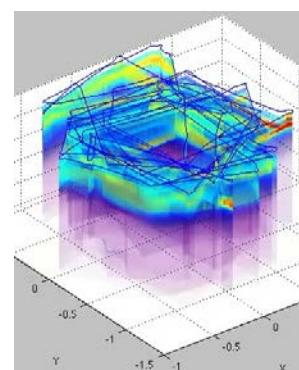


Fig.2 A Lagrangian 1 Km X 1 Km box around an advecting drifter.



Fig.3 The September advecting patch cruise 100 Nm from the California coast with the R/V Flyer in the distance.

STUDENT RESEARCH: IN-PROGRESS

LT STEVE HALLE & LT JASON HICKLE

THE DESIGN AND IMPLEMENTATION OF AN AUTONOMOUS SURF ZONE ROBOT USING ADVANCED SENSORS AND A COMMON ROBOT OPERATING SYSTEM



Surf zone operations provide unique challenges to unmanned systems. This project, nicknamed "MONTe", is being developed to produce a semi-autonomous reconnaissance platform designed to operate in that environment. The concept of operation is to deploy the unit from the sea and transition to the shore under its own propulsion. Once ashore, the system will navigate, avoid obstacles, and accomplish mission parameters provided by the operator.

Current development efforts are threefold. The first is construction of a waterproof chassis and drive system that is robust enough to withstand harsh surf conditions. Water jets will provide thrust while floating near the surface and land-based locomotion is provided by wheel/legs (Whegs)™. A biologically inspired tail will assist in climbing adverse terrain and provide the ability to right itself. Second is the control system design. The semi-autonomous control is being implemented on a Linux based system with Robot Operating System (ROS) from Willow Garage Inc. ROS is open-source software that operates using a publish/subscribe format. The last focus of development is integration of sensors and communication. A wireless 802.11N link will be used to remotely interact with the robot. Additional sensors, such as GPS receivers and Attitude and Heading Reference Systems (AHRS), will be integrated for improved control and autonomy.

NPS Students to research Cargo UAS Viability

by Eric Pratson, NAVAIR

PMA-266 is the multi-mission, tactical unmanned aerial system program office at NAVAIR. It is responsible for the development, acquisition and fielding of rotary-winged UAVs. Beginning in early 2009, PMA-266 teamed with the Marine Corp Warfighting Laboratory, (MCWL) to assess the feasibility of unmanned systems for aerial cargo resupply missions. Since an initial demonstration of two systems, Boeing Hummingbird and Kaman/Lockheed Martin K-MAX helicopters at Dugway Proving Grounds, UT in 2010, the program has contracted the aforementioned suppliers to develop systems capable of development to Afghanistan.

The current effort will result in one system being deployed following a Quick Reaction Assessment (QRA) in August 2011. The requirement for a cargo UAS is based on a joint urgent operational need to counter risks from IEDs. The intent is to reduce the number of trucks delivering supplies to forward operating bases. Following the QRA, one supplier will be fielded for a six-month military utility assessment in Afghanistan where CONOPs will be refined and the system's operational value will be evaluated. Currently three Naval Postgraduate School students, Maj Les Payton USMC, Capt Troy Peterson USMC and LT Jason Staley USN are actively engaged in developing thesis work on cargo UAS. Their efforts will help inform the DoD whether this type of capability is viable for the future.

Thesis Topic Submission by DoD Organizations

Does your DoD Organization have a potential graduate thesis topic related to unmanned systems they would like to find NPS students to research? Please contact Lisa at cruser@nps.edu for additional information. CRUSER has funds for student travel to support thesis research and attend experiments in CRUSER related topics.

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The CRUSER Calendar of Events is located on our Wiki:

<https://wiki.nps.edu/display/CRUSER/>

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http://www.nps.edu/Research/cruser/cruser_EventSub_Form.html

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